

# Optimal Server Allocation and Frequency Modulation on Multi-Core Based Server Clusters

Xinying Zheng, Michigan Technological University, USA

Yu Cai, Michigan Technological University, USA

---

## ABSTRACT

*Multi-core processing has been widely used in high-performance computing systems. Power reduction and energy conservation are important in these systems to minimize operating cost. Two main strategies exist for power management: Dynamic Voltage/Frequency Scaling (DV/FS) and server number controlling: Vary-On Vary-Off (VOVF). In this paper, the authors explore the benefits of DV/FS and VOVF and apply them in a multi-core based server cluster. An optimization problem is formulated to get the optimal resource scheduling strategy given a parallel workload. The presented optimization model provides controllable and quantitative power consumption with theoretically guaranteed service performance. The authors further study the overhead of the proposed scheme and provide a Double Control Periods (DCP) method to compensate the transition overhead. The power optimization model is evaluated via extensive simulations. It is also justified by the real workload data trace. The results prove the effectiveness and efficiency of the proposed model.*

*Keywords:* Dynamic Voltage Scaling, Green Computing, Multi-Core Based Server Cluster, Parallel Computing, Server Cluster

---

## INTRODUCTION

Green computing is used to support personal and business computing needs in a green and sustainable manner, such as minimizing strain and impact on resources and environment. Computing systems, particularly enterprise data centers and high-performance cluster systems consume a significant amount of energy, thus placing an

increasing burden on power supply and operational cost. It is estimated that servers consume 0.5 percent of the world's total electricity usage, which if current demand continues, is projected to quadruple by 2020 (Tedre, Chachage, & Faida, 2009). The Environmental Protection Agency recently reported that the energy used by data centers by the year 2011 is estimated to cost \$7.4B (Jiang & Parashar, 2009). Some analysts predicted that IT infrastructure will soon cost more on power consuming than the

DOI: 10.4018/jgc.2010070102

hardware the hardware itself (Chen, Das, Qin, Sivasubramaniam, & Wang, 2005).

Many of the existing work on power management in server clusters are software based with hardware support. The primary principle in green computing is to achieve energy efficiency with performance guaranteed. Two main mechanisms are commonly used for energy saving: DV/FS dynamically changed the frequency and voltage of servers to produce energy saving (Vasic, Garcia, Oliver, Alou, & Cobos, 2008; Pinheiro, Bianchini, Carrera, & Heath, 2001); VOVF used server turn off/on mechanism for power management (Fan, Weber, & Barroso, 2007; Guerra, Leite, & Fohler, 2008; Sharma, Bash, Patel, & Friedrich, 2005). A few work considered integrating both DV/FS and VOVF mechanisms together (Chen et al., 2005; Nedeveschi, Popa, Iannaccone, & Ratnasamy, 2008). Applying DV/FS and VOVF should take careful considerations of transition overhead, which not only leads to performance degradation but also reduce the life cycle of hardware components. However, the transition overhead was not well studied in the literature.

Amdahl's Law provides a simple but extremely useful method to predict the potential performance of a parallel computer given the ratio of the serial and parallel portion and the number of processors. Recently, Amdahl's law has been extended to investigate the performance and energy consumption of a multi-core computer and server clusters (Ge, Feng, & Cameron, 2009; Cho, Rami, & Melhem, 2008). These work use service time as performance metric without considering the waiting time of incoming requests.

This paper establish an optimization power model which takes advantages of both DV/FS and VOVF mechanisms to achieve energy efficiency with guaranteed responds time in a multi-core based server cluster. A novel double control periods strategy is proposed to compensate the transition overhead. The rest of this paper is organized as follows. The

related work is presented. The power model and performance metric model are introduced. The optimization problem is formulated and the solving method provided. The transition overhead is then studied. The optimization model is also evaluated.

## RELATED WORK

In recent years, power management has become one of the most important concerns on server clusters. Many previous work achieves energy saving by dynamically adjust processors' frequency and voltage. Researchers have developed various DV/FS scheduling algorithms to save energy under timing deadlines (Vasic et al., 2008; Pinheiro et al., 2001). VOVF is a major policy applied in server clusters (Fan et al., 2007; Guerra et al., 2008; Sharma et al., 2005). In (Niyato, Chaisiri, & Sung, 2009), researchers constructed a constraint Markov model to adjust server numbers according to transition probability. In (Nedeveschi et al., 2008), the authors proposed a method to reduce network energy consumption via sleeping and rate adaptation via combining VOVF and DV/FS. Combining DV/FS and VOVF potentially provide higher energy saving.

Feedback control theoretic approaches for energy efficient solutions have been proposed by a number of researchers (Wang & Chen, 2008). Sharma et al. (Sharma, Thomas, Abdelzaher, Skadron, & Lu, 2003) proposed feedback control schemes to control application-level quality of service requirements. Chen et al. (Dovrolis, Stiliadis, & Ramanathan, 1999) presented a feedback controller to manage the response time in server clusters. Some researchers applied DTM on a complete data center rather than individual servers or chips. In (Sharma et al., 2005), the authors proposed policies for workload placement to promote uniform temperature distribution using active thermal zones.

Virtualization is another key strategy to reduce power consumption in enterprise networks.

11 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: [www.igi-global.com/article/optimal-server-allocation-frequency-modulation/48839](http://www.igi-global.com/article/optimal-server-allocation-frequency-modulation/48839)

## Related Content

---

### Is Gender a More Important Axis of Representation Than Race, Ethnicity or Class in Politics?

Abu Saleh Mohammad Sowad (2019). *International Journal of Social Ecology and Sustainable Development* (pp. 29-36).

[www.irma-international.org/article/is-gender-a-more-important-axis-of-representation-than-race-ethnicity-or-class-in-politics/221372](http://www.irma-international.org/article/is-gender-a-more-important-axis-of-representation-than-race-ethnicity-or-class-in-politics/221372)

### Strategies for Reducing the Environmental Impact of Impulse Buying

Svetlana Obukhovich, Jenni Sipilä and Anssi Tarkiainen (2023). *Sustainable Marketing, Branding, and Reputation Management: Strategies for a Greener Future* (pp. 195-211).

[www.irma-international.org/chapter/strategies-for-reducing-the-environmental-impact-of-impulse-buying/330799](http://www.irma-international.org/chapter/strategies-for-reducing-the-environmental-impact-of-impulse-buying/330799)

### Long-Term Performance Evaluation of Groundwater Chlorinated Solvents Remediation Using Nanoscale Emulsified Zerovalent Iron at a Superfund Site

Chunming Su, Robert W. Puls, Thomas A. Krug, Mark T. Watling, Suzanne K. O'Hara, Jacqueline W. Quinn and Nancy E. Ruiz (2020). *Waste Management: Concepts, Methodologies, Tools, and Applications* (pp. 1352-1371).

[www.irma-international.org/chapter/long-term-performance-evaluation-of-groundwater-chlorinated-solvents-remediation-using-nanoscale-emulsified-zerovalent-iron-at-a-superfund-site/242765](http://www.irma-international.org/chapter/long-term-performance-evaluation-of-groundwater-chlorinated-solvents-remediation-using-nanoscale-emulsified-zerovalent-iron-at-a-superfund-site/242765)

### Business Transformation Projects: The Role of Psychology-Based Resistance (RPbR)

Antoine Toni Trad (2023). *Considerations on Education for Economic, Social, and Environmental Sustainability* (pp. 423-457).

[www.irma-international.org/chapter/business-transformation-projects/323352](http://www.irma-international.org/chapter/business-transformation-projects/323352)

## Relationship between Governance, Performance and Solvency: An Empirical Test in Italian Unlisted Family SMEs

Francesco Campanella and Domenico Graziano (2013). *International Journal of Social Ecology and Sustainable Development* (pp. 1-19).

[www.irma-international.org/article/relationship-between-governance-performance-and-solvency/101381](http://www.irma-international.org/article/relationship-between-governance-performance-and-solvency/101381)